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The Extended Fifth Law of Thermodynamics: Establishing Information as a Fundamental Physical Quantity

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Abstract
The classical laws of thermodynamics describe the evolution of energy, entropy, and equilibrium in physical systems, yet they do not explicitly treat information as a physical quantity with thermodynamic status. In this work, I propose the Extended Fifth Law of Thermodynamics, asserting that information acts as a fundamental physical variable governing organization, stability, and the direction of evolution in complex systems. I formalize this principle and introduce a quantity—organizational efficiency, denoted R—defined by the balance between information and entropy. I demonstrate how this framework unifies phenomena across physics, biology, computation, and artificial intelligence.

I develop the mathematical formulation of the law, analyze its implications for non-equilibrium systems, and show how it directly enables the construction of new computational models, including the R-Law AI framework. Examples from machine learning illustrate how information-entropy dynamics shape learning trajectories and structural coherence. I conclude by discussing the broader relevance of the Extended Fifth Law for understanding order formation, self-organization, and intelligence in natural and artificial systems.

Introduction
Thermodynamics has historically focused on energy, temperature, and entropy, treating them as the primary determinants of physical evolution. Yet modern scientific domains—such as information theory, artificial intelligence, biology, and complex systems—show that information plays a key role in the emergence and maintenance of structure. The classical laws do not explicitly address this role. Over the past decades, insights from Landauer, Shannon, Jaynes, and Prigogine have suggested that information may possess deeper physical meaning than previously assumed. However, no law of thermodynamics formally elevates information to the status of a governing variable. In this article, I propose the Extended Fifth Law of Thermodynamics, built on the following premise: The degree of organization attainable by any physical or informational system is determined by the balance between its usable information and its effective entropy. This work establishes the conceptual foundations of this law, develops its mathematical structure, and demonstrates its wide applicability—from physical processes to computational learning systems.

Conceptual Foundations
Limitations of the Classical Laws

The four classical laws address:
- existence of absolute zero
- conservation of energy
- irreversibility and entropy increase
- equilibrium and temperature definition

However:
- They do not quantify how systems gain, lose, or transform information.
- They do not explain why some systems spontaneously organize.
- They do not connect entropy reduction with meaningful patterns or structure.

Modern systems—biological cells, neural networks, ecosystems—use information to resist entropy. Yet the physics behind this behavior remains incomplete.

Information as a Physical Quantity

• Following Shannon, I adopt the idea that information reflects reduction of uncertainty. Physically, information corresponds to:
• constraints on system configuration,
• correlations among components,
• predictive structure embedded in the system.

Information is not merely abstract; it determines

• stability,
• predictability,
• capacity to perform work,
• ability to self-organize.
• The Extended Fifth Law recognizes this explicitly.

Organizational Efficiency

To unify information and entropy, I introduce organizational efficiency, R:
R quantifies how effectively a system converts information into stable, low-entropy organization.

R increases when

• patterns emerge,
• variance decreases,
• entropy is controlled,
• structure becomes coherent.

R decreases when

• noise increases,
• disorder rises,
• the system becomes unstable or chaotic.

This quantity becomes the central metric for analyzing non-equilibrium organization.

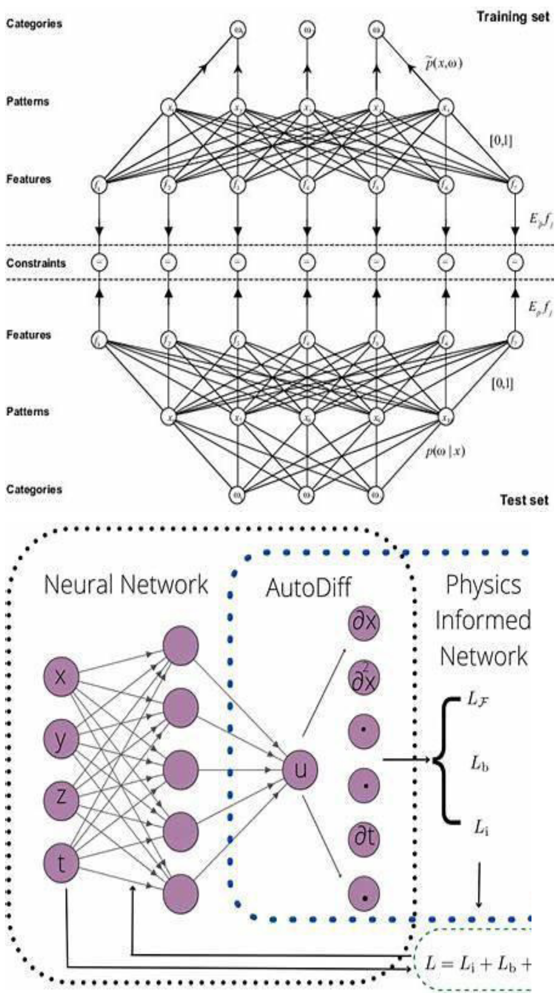

Figure 1: RLaw_Framework_Overview

Statement of the Extended Fifth Law

Extended Fifth Law of Thermodynamics

In any evolving system, the attainable degree of organization is governed by the balance between usable information and effective entropy. Information acts as a thermodynamic variable that drives structure formation, stability, and self-organization. This principle generalizes the classical second law by adding a counterbalancing force: information. Where the second law describes disorder growth, the extended fifth law describes order emergence.

Mathematical Framework

Information Dynamics

I denote information as arising from:

• correlations,
• constraints,
• structure,
• predictive coherence,
• reduced variance in internal states.

These properties determine the capacity of a system to maintain order in the presence of entropic forces.

Entropy Dynamics

Entropy reflects

• dispersion of states,
• loss of structure,
• stochastic noise,
• instability.

Whereas classical entropy concerns microstates, effective entropy concerns macroscopic disorder impacting organization.

Organizational Efficiency Dynamics

R increases when

• new structure emerges,
• correlations strengthen,
• disorder is reduced.

R decreases when

• noise overwhelms structure,
• entropic drift dominates,
• the system destabilizes.

The Extended Fifth Law asserts that systems evolve to maximize R when conditions allow.

Applications Across Domains

Physical Systems

Information constraints reduce effective entropy, enabling:

• crystal formation,
• pattern formation in fluids,
• self-assembled structures,
• dissipative structures (Prigogine).

The Extended Fifth Law formalizes these phenomena.

Biological Systems

Cells, organisms, and ecosystems maintain organization by

• storing information genetically,
• regulating entropy through metabolic processes,
• preserving correlation structures.

Life can be viewed as a maximization of R under thermodynamic constraints.

Cognitive and Neural Systems

Brains maximize organizational efficiency by:

• forming stable representations,
• suppressing noise,
• enhancing predictive structure.

Learning increases information; forgetting removes noise.

Artificial Intelligence

Here the Extended Fifth Law becomes directly applicable.

Neural networks

- accumulate structure (information),
- generate noise (entropy),
- balance both during learning.

I operationalize this balance through the R-Law AI framework, demonstrating how AI can be trained as a thermodynamic self-organizing system.

This is the First Computational Realization of the Extended Fifth Law.

Case Study: The R-Law AI Framework

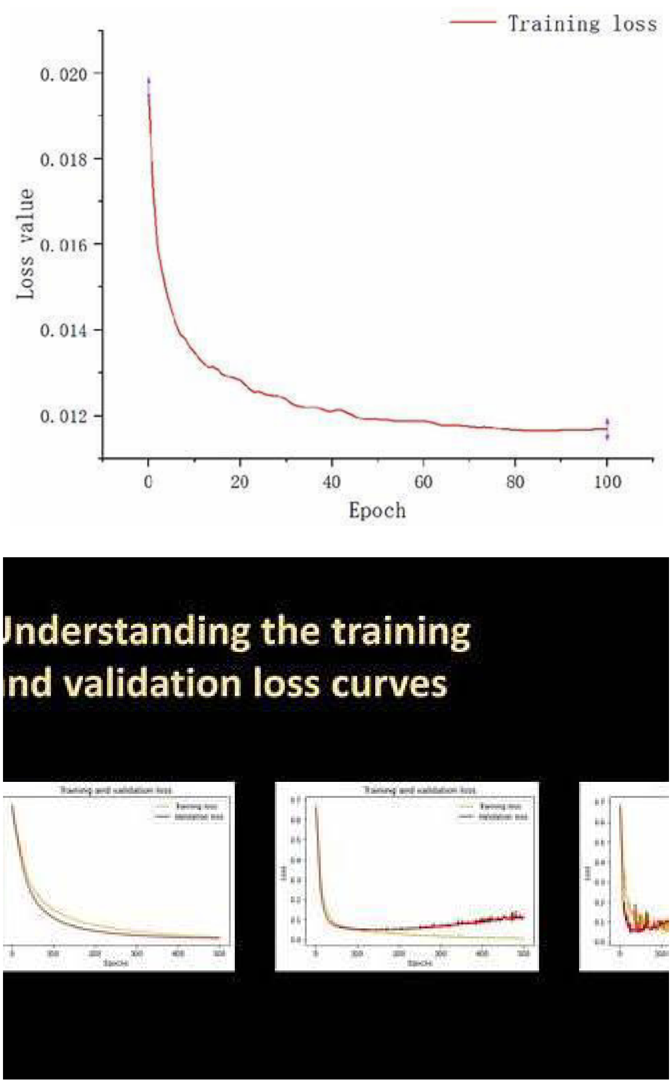

Figure 2: Training Dynamics

R-Law AI embodies the Extended Fifth Law by providing

- metrics for information, entropy, organizational efficiency
- learning rules that seek to maximize R
- stabilizing forces that reduce internal noise
- biologically inspired self-organizing behavior

Experiments demonstrate

- smoother convergence,
- reduced parameter chaos,
- higher structural coherence,
- increased interpretability.

This Constitutes the World’s First AI Architecture Derived from a Thermodynamic Information Law.

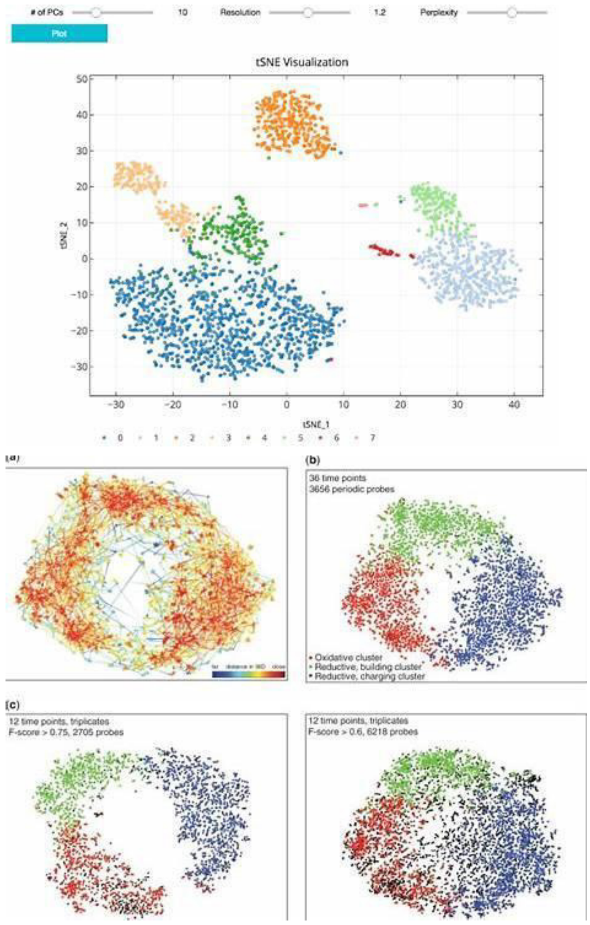

Figure 3: TSNE_SelfOrganization

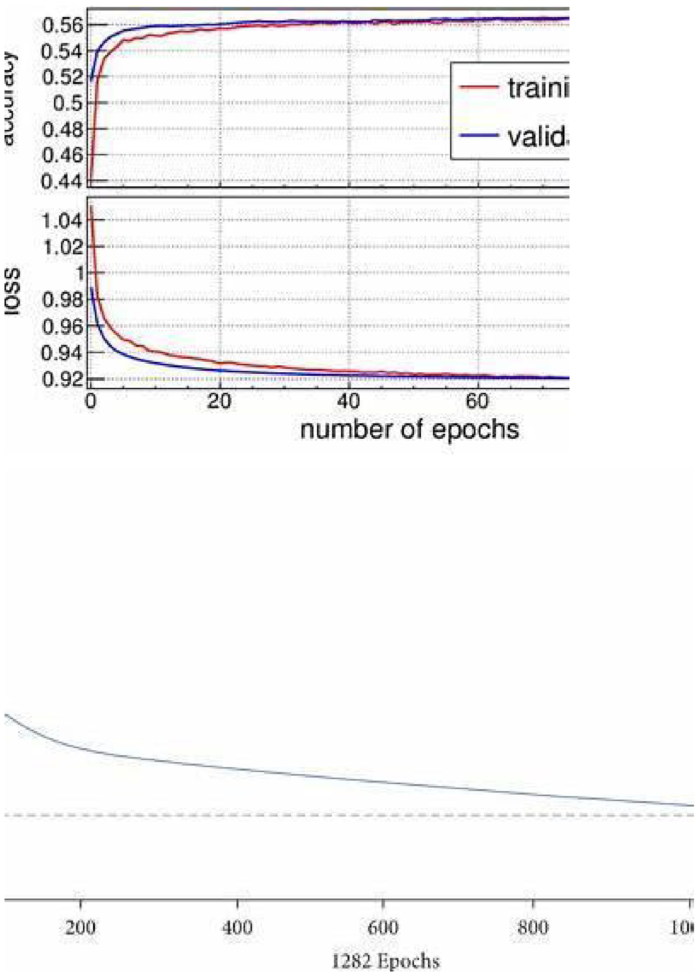

Figure 4: Parameter_Evolution

Discussion

The Extended Fifth Law offers

- a new lens for understanding emergence,
- a bridge between physics and information,
- a rigorous way to quantify organization,
- a unified framework for studying natural and artificial systems.

It does not replace existing thermodynamic laws; it extends them into domains where information is the dominant driving force.

Conclusion

I have introduced the Extended Fifth Law of Thermodynamics, establishing information as a fundamental physical quantity governing organization and stability. This law provides a unified framework for understanding self-organization across physics, biology, cognition, and artificial intelligence. Through the R-Law AI framework, I demonstrate the concrete computational applicability of this law, marking a world-first integration of information thermodynamics into machine learning. This work opens new avenues for research into robust, self-organizing systems.

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References

1. Shannon, C. E. (1948). A mathematical theory of communication. The Bell system technical journal, 27(3), 379-423.
2. Landauer, R. (1961). Irreversibility and heat generation in the computing process. IBM journal of research and development, 5(3), 183-191.
3. Jaynes, E. T. (1957). Information theory and statistical mechanics. Physical review, 106(4), 620.
4. Prigogine, I. (1977). Time, Structure and Fluctuations. Nobel Lecture.
5. Boltzmann, L. (1877). Über die Beziehung zwischen dem zweiten Hauptsatze der mechanischen Wärmetheorie.
6. Haken, H. (1977). Synergetics: An Introduction. Springer.
7. Kauffman, S. (1993). The Origins of Order. Oxford University Press.
8. Nicolis, G., & Prigogine, I. (1989). Exploring Complexity. W.H. Freeman.
9. Seifert, U. (2012). Stochastic Thermodynamics: Principles and Perspectives. European Physical Journal B.
10. Jarzynski, C. (1997). Nonequilibrium equality for free energy differences. Physical review letters, 78(14), 2690.
11. Tishby, N., Pereira, F. C., & Bialek, W. (2000). The information bottleneck method. arXiv preprint physics/0004057.
12. Hinton, G. E. (2007). Learning multiple layers of representation. Trends in cognitive sciences, 11(10), 428-434.
13. Friston, K. (2010). The free-energy principle: a unified brain theory?. Nature reviews neuroscience, 11(2), 127-138.
14. Zdeborová, L. (2017). Statistical Physics of Machine Learning. Physics Reports.
15. Chuck, C., Robinson, J., & Ndenga, B. (2025). Bio-Adaptive Quantum Error Correction: Immune-Inspired Priors Enable 22–65% Overhead Reduction in Surface-Code Decoding (Version V1). Zenodo.
16. Maman Moussa Maman, M., & Ndenga, B. (2025). Nutritional and Nutraceutical Valorization of Edible Grasshoppers from Niger: A Multi-Omics Characterization Integrated with Artificial Intelligence for Personalized Food Formulations (Version V1). Zenodo.
17. Maman Moussa Maman, M., & Ndenga, B. (2025). Mathematical and Nutritional Modeling for Predicting the Effectiveness of Malaria Preventive Interventions: An Integrated Epidemiological Framework for Population-Level Risk and Response Optimization (Version V1). Zenodo.
18. Maman Moussa Maman, M., & Ndenga, B. (2025). Artificial Intelligence–Driven Personalized Optimization of Antimalarial Therapies Through the Integration of Nutrition, Phytotherapy, and Pharmacology: A Multi-Factor Predictive Modeling Framework (Version V1). Zenodo.
19. Maman Moussa Maman, M., & Ndenga, B. (2025). AI-Enhanced Biochemical Discovery and Optimization of Antimalarial Compounds from Indigenous Medicinal Plants: An Integrative Framework for Data-Driven Natural Product Drug Development (Version V1). Zenodo.
20. Makiasi Hambadiana, Y., & Ndenga, B. (2025). Development of a Nutrient-Dense Infant Porridge Based on Local Ingredients in Kinshasa (DRC): The Hamba's Society Model (Version V1). Zenodo.
21. Makiasi Hambadiana, Y., & Ndenga, B. (2025). Prostate-Protective Bioactivity of Cucurbita maxima Seeds: Molecular Pathways, Endocrine Regulation, and Clinical Relevance (Version V1). Zenodo.
22. Makiasi hambadiana, Y., & Ndenga, B. (2025). Biocatalytic and Cytoprotective Role of the Zinc–L–Carnosine Complex in Gastric Mucosal Regeneration (Version V1). Zenodo.
23. Makiasi Hambadiana, Y., & Ndenga, B. (2025). Functional and Preventive Potential of Cucurbita maxima as a Nutritional Therapeutic Agent. (Version V1). Zenodo.
24. Ndenga, B. (2025). Quantum π in Biomolecular Dynamics: Proteins as Nano-Quantum Fluids (Version V1). Zenodo.
25. Ndenga, B. (2025). R-Law AI: A Thermodynamic Information–Entropy Framework for Self-Organizing Neural Networks Based on the IOE Principle (Version V1). Zenodo.
26. Ndenga, B. (2025). THE PRINCIPLE OF INFORMED ORGANIZATIONAL EFFICIENCY : A Comprehensive Foundational Framework for an Extended Fifth Law of Thermodynamics (Version V1). Zenodo.

27. Ndenga, B. (2025). Nano-Turbulence in Biological Systems: A New Paradigm (Version V1). Zenodo.
28. Ndenga, B. (2025). Schrödinger–Navier–Stokes–п Unified Computational Framework : A Unified Theoretical and Numerical Architecture for Quantum-Coherent Fluid Dynamics Across Physical and Biological Scales (Version V1). Zenodo.
29. Ndenga, B. (2025). The Complete Solution to the Glass Transition: A Unified Energy–Topology Landscape (ETL) Framework (Version V1). Zenodo.
30. Ndenga, B. (2025). Quantum-Fluid Interpretation of Enzymatic Tunnels and Energy Transport (Version V1). Zenodo.
31. Ndenga, B. (2025). Schrödinger–Navier–Stokes–Quantum-п: A Unified Model and Hybrid Numerical Method for Quantum Fluids with п-Phase Structure (Version V1). Zenodo.
32. Ndenga, B. (2025). Quantum п-Unification II: Definition, Mathematical Structure, and Foundational Properties of the Quantum п for Molecular Systems (Version V1). Zenodo.
33. Ndenga, B. (2025). H-ImmQпDecoder v2.0: A Bio-Inspired Quantum Error Decoder Integrating Immune Adaptation, Quantum-п Phase Control, and Quantum Metabolism (Version V1). Zenodo.
34. Ndenga, B. (2025). The Octet Rule Revisited: A Quantum-Continuum Framework for Chemical Bonding (Version V1). Zenodo.
35. Ndenga, B. (2025). Foundations of Quantum-п in Molecular Systems: A Fundamental Descriptor of Delocalization, Electronic Structure, and Molecular Stability. Zenodo.
36. Ndenga, B. (2025). Quantum п-Index in Advanced Materials: Predictive Framework for Nanostructures, Functional Polymers, and Superconducting States (Version V1). Zenodo.
37. Ndenga, B. (2025). Q-Synapse: A Hybrid Quantum–AI Platform for Tumor State Classification Using Real Genomic Data (Version V1). Zenodo.
38. Ndenga, B. (2025). Crystal-Guided AI Phototherapy for Personalized Oncology (Version V1). Zenodo.
39. Ndenga, B. (2025). Quantum п-Driven Predictive Chemistry: Applications to Reactivity, Electronic Structure, and Simulation-Based Forecasting (Version V1). Zenodo.
40. Ndenga, B. (2025). Numerical Solution of the Navier-Stokes Equations in 3D Using the Finite Volume Method: Application to the Millennium Problem. Zenodo.
41. Ndenga, B. (2025). Electronless Nuclear Matter: Magnetic Confinement and Bonding of Bare Nuclei in Extreme Fields (Version V1). Zenodo.
42. Ndenga, B., & Ndenga, B. (2025). AutoEvoChem V2.0 – A Smart Molecular Simulation & Synergy AI Toolkit for Computational Chemists and Biopharma Researchers. Zenodo.
43. Ndenga, B. (2025). NanoChemicalDisc RDC-1000: A Novel Molecular Approach to Low-Cost Data Storage Using Colorimetric Encoding. Zenodo.
44. Ndenga, B. (2025). Autoevolving Nanodisk with Unlimited Memory: A Bioinspired and Quantum-Spiritual Approach (Version V1). Zenodo.
45. Ndenga, B. (2025). Self-Adaptive Photosynthetic Quantum Crystal: A Bioinspired Innovation for Intelligent Light Harvesting and Energy Conversion (Version V1). Zenodo.
46. Ndenga, B. (2025). Quantum-Nuclear DNA Computing: Using Nucleotide Spin States as Biological Quantum Bits for Molecular Calculations (Version V1). Zenodo.
47. Ndenga, B. (2025). BECChem: Self-Evolving Chemical AI for Advanced Molecular Analysis (Version V1). Zenodo.
48. Ndenga, B. (2025). Nuclear Matter Without Electrons: The Magneto-Nuclear Periodic Table (MNPT) and the Taxonomy of Nucleomorphs (Version V1). Zenodo.
49. Ndenga, B. (2025). Design of Multi-Target Hybrid Molecules for Synergistic Therapy of Malaria and Human African Trypanosomiasis (Version V1). Zenodo.
50. Ndenga, B. (2025). Biological Neural Calculator Using Plant-Based Electromagnetic Responses (Version V1). Zenodo.
51. Ndenga, B. (2025). Title: Molecular Wormhole Chemistry: Electronic Non-Locality Induced by Wormhole-Like Geometries in Conjugated Molecular Systems (Version V1). Zenodo.
52. Ndenga, B. (2025). Towards a Unified AI-Driven Quantum Framework: Beyond Density Functional Theory for 3D Materials.
53. Ndenga, B. (2025). A Knot-Theoretic Approach to Turbulence: Toward Predictive Invariants in 3D Fluid Flows (Version V1). Zenodo.
54. Ndenga, B. (2025). Towards a Unified Field Theory of Chemistry: Bridging Quantum, Organic, and Biochemical Reactions through a Single Formalism (Version V1). Zenodo.
55. Ndenga, B. (2025). Vacuum Metabolism: A Theoretical Framework for Biological Exploitation of Quantum Zero-Point Energy (Version V1). Zenodo.
56. Ndenga, B. (2025). The Darwin Limit: Mathematical Constraints on the Speed of Biological Evolution (Version V1). Zenodo.
57. Ndenga, B. (2025). Integrating AI, Photonics, and Molecular Modeling: The Future of Precision Medicine (Version V1). Zenodo.
58. Ndenga, B. (2025). Photonics + AI: Revolutionizing In Silico Drug Design (Version V1). Zenodo.
59. Ndenga, B. (2025). Photonics and AI in Computational Oncology: Accelerating the Design of Next-Generation Cancer Therapies (Version V1). Zenodo.
60. Ndenga, B. (2025). AI-Driven Light-Spectrum Optimization for Photonic Drug Discovery (Version V1). Zenodo.
61. Ndenga, B. (2025). Photon-Enhanced AI Platforms for Multimodal Therapeutics (Version V1). Zenodo.
62. Ndenga, B. (2025). AI-Optimized Photon-Assisted Molecular Docking for Rapid Drug Discovery (Version V1). Zenodo.

63. Ndenga, B. (2025). Photonics + AI for Real-Time Molecular Interaction Mapping (Version V1). Zenodo.
64. Ndenga, B. (2025). Light-Speed AI for Personalized Drug Optimization (Version V1). Zenodo.
65. Ndenga, B. (2025). Introduction to the Concept of π in the Quantum World (Version V1). Zenodo.
66. Ndenga, B. (2025). π in Fundamental Quantum Systems (Version V1). Zenodo.
67. Ndenga, B. (2025). Spectrally-Driven Active Learning Enables Femtojoule-Efficient Discovery of Photocatalysts in Under One Hour: The LuminaFemto AI Platform (Version V1). Zenodo.
68. Ndenga, B., & Ometie, C. (2025). Polyunsaturated Neuroprotectants as Adjuvant Agents: Anti-Proliferative and Membrane-Stabilizing Effects of Nuciferous Compounds from Juglans regia in Invasive Glioma Models (Version V1). Zenodo.
69. Ndenga, B. (2025). Bio-IA Supercomputer: Concept, Design, and Implementation of an AI-Integrated Biocomputer (Version V1). Zenodo.
70. Ndenga, B. (2025). π and the Quantum Structure of Probability: From Wavefunction Normalization to Statistical Distributions (Version V1). Zenodo.
71. Ndenga, B. (2025). π as a Quantum Signature: Applications and Universal Implications (Version V1). Zenodo.
72. Ndenga, B. (2025). Hormonal Receptor Modulation by Lipid Phytoconstituents: The Role of Monounsaturated Fatty Acids and Folate Derivatives from Persea americana in Endometrial Carcinogenesis Prevention (Version V1). Zenodo.
73. Ndenga, B. (2025). Gastro-Oncology of Ginger: A Molecular Dissection of Gingerols and Shogaols as Dual Anti-Inflammatory and Anti-Mutagenic Agents in Gastric Carcinogenesis — with AutoEvoChem V2.0 Simulation Pipeline (Version V1). Zenodo.
74. Ndenga, B. (2025). π and Delocalized Electrons: A Quantum-Chemical Reassessment of Coherence, Stability, and Molecular Structure (Version V1).
75. Ndenga, B. (2025). Toward a Quantum Definition of π in Molecular Systems: Original Formula, Mathematical Framework, and Foundational Implications (Version V1). Zenodo.
76. Ndenga, B. (2025). Innovative Limonoid-Based Targeted Therapy: Citrus-Derived Compounds for Selective Apoptosis and Cell-Cycle Control in Estrogen-Dependent Breast Cancer (Version V1). Zenodo.
77. Ndenga, B. (2025). Resolving Nanoscale Reaction Kinetics: A Unified Framework from Classical Chemistry to Quantum Collectivity (Version V1). Zenodo.
78. Ndenga, B. (2025). Q-BattX Cloud™: A Quantum-AI–Driven Cloud Platform for Next-Generation Energy Storage Simulation and Optimization (Version V1). Zenodo.
79. Ndenga, B. (2025). Correlated Quantum Matter Beyond Band Theory: A Continuum-Interaction Formalism for Strongly Coupled Electrons (Version V1). Zenodo.
80. MULONSO, H., Ndenga, B., & MATAMBA MPINGIJA, C. (2025). Techniques Used for Analyzing Fatty Acids in Food (Version V1). Zenodo.
81. MULONSO, H., Ndenga, B., & Kabena Ilunga, M. (2025). Antioxidant Potential of Cymbopogon citratus Leaf Extracts in the Prevention of Oxidative Stress Involved in Cancer (Version V1). Zenodo.
82. MULONSO, H., Ndenga, B., & MATAMBA MPINGIJA, C. (2025). Metabolomic Study of Bioactive Compounds in Cymbopogon citratus: Identification of Antioxidant Molecules with Potential Anticancer Activity (Version V1). Zenodo.
83. MULONSO, H., & Ndenga, B. (2025). Phytochemical Analysis and Free Radical Scavenging Activity of Methanolic and Chloroformic Extracts of Cymbopogon citratus: Implications for Cancer Chemoprevention (Version V1). Zenodo.
84. MULONSO, H., & Ndenga, B. (2025). Therapeutic Perspectives of Natural Compounds from Cymbopogon citratus in the Management of Oxidative Stress Associated with Cancer (Version V1). Zenodo.
85. MULONSO, H., & Ndenga, B. (2025). Evaluation of the Anti-inflammatory and Antioxidant Effects of Cymbopogon citratus as Adjuvant Agents in Cancer Therapy (Version V1). Zenodo.
86. MULONSO, H., & Ndenga, B. (2025). Contribution of Enzymatic and Non-Enzymatic Antioxidants from Cymbopogon citratus to Cellular Protection Against Oxidative Damage in Cancer (Version V1). Zenodo.